

is its ability to embody indirect cost effects, which are likely to loom largely for the types of "non-incremental" incremental changes on which the FCC is focused. We believe that, if experience is any guide, reconciliation of top-down and bottom-up estimates will result in higher cost proxies than heretofore deemed appropriate by the FCC. In any event, top-down estimates can be a useful tool for regulators who are faced with determining costs for a variety of purposes, including interconnection, unbundling, universal service and pricing reforms.

A New Set of "Top-Down" Incremental Cost Measures

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(Revised)

I. Introduction

The FCC, in its "Interconnection Order,"¹ has held that forward-looking incremental costs provide an economically appropriate basis for establishing rates for competitive interconnection elements. A good deal of controversy surrounds this conclusion; opponents question both the efficiency and equity of this approach.² In addition to endorsing the conceptual efficacy of forward-looking incremental costs, the Commission has also utilized empirical estimates of costs to establish default rates. These rates are deemed to supply a reasonableness standard upon which state regulators may rely in the near-term absence of cost studies focused on specific conditions prevailing within particular jurisdictions.³

The studies upon which the FCC has relied in establishing its default rates are based on a "bottom-up" approach to cost estimation. That approach involves a *de novo* analysis relating activity

¹ Federal Communications Commission, *In the Matter of Implementation of the Local Competition Provisions in the Telecommunications Act of 1996; Interconnection between Local Exchange Carriers and Commercial Mobile Radio Service Providers*, CC Dockets No. 96-98 and 95-185, *First Report and Order* (adopted August 1, 1996, released August 8, 1996) and *Order on Reconsideration* (adopted and released September 27, 1996).

² While rates that recover incremental costs are subsidy-free by some economic definitions, they may also be economically inefficient, insufficient to guarantee the viability of the regulated firm, inconsistent with achievement of various social objectives, and a legal breach of the historical regulatory administrative contract.

³ A federal appeals court recently "stayed" implementation of the FCC's cost proxies pending formal adjudication of their legality (*Iowa Utilities Board v. FCC*, Case Nos. 96-3321, *et seq.*, *Stay Order*, October 15, 1996).

levels to cost drivers in a hypothetically optimal engineering model of a synthetic network. The bottom-up approach is not the only method available to derive estimates of forward-looking incremental costs. Alternative approaches to cost estimation, notably a "top-down" approach, can also be utilized to produce cost estimates.⁴ The top-down approach draws *inferences* about forward-looking costs on the basis of econometric analysis of cost relationships within existing networks. In this study we report the results of our effort to derive estimates of forward-looking incremental costs using a top-down approach.

In principle, application of different approaches to empirical estimation of particular costs should produce similar results. Where there are differences, it should be possible to reconcile conflicting results, *i.e.*, to understand what accounts for differences and make suitable adjustments to produce comparable results.⁵ While we have not attempted a full-scale reconciliation of the differences between our results and those of previous efforts, we think we can plausibly account for the differences that apparently exist between top-down and bottom-up cost estimates. If our assessment is correct, it is likely that *the Commission's current default rates tend to understate actual forward-looking incremental costs.*

⁴ In an earlier submission to the FCC, we described the alternative approaches to cost estimation in some detail, offering a taxonomy of different models along with some rudimentary estimates of loop costs based on a top-down approach. See J. Haring, C. S. Monson and J. H. Rohlf. *Comments on FCC's Industry Demand and Supply Simulation Model* (July 8, 1996) [available at <http://www.spri.com>].

⁵ In our earlier submission to the FCC, we referred to the United Kingdom Office of Telecommunications' (OfTel's) formal effort to reconcile differences between top-down and bottom-up estimates of telecommunications costs in the U.K. This effort has resulted in cost estimates somewhat higher than those suggested by a bottom-up analysis considered by itself. See *Ibid.*, and the references cited therein.

Two important implications follow: If rates are established at (or below) the levels of the FCC's *below-cost* default rates, they will, in addition to any other economic disabilities they may suffer, *not* be subsidy-free. Such rates can, therefore, be reasonably anticipated to increase the cost burden to be recovered through charges for other services.⁶ Rates set below true incremental costs are also liable to deter efficient competition and thus thwart achievement of the regulatory objective which motivates requirements for unbundled offerings in the first place.

Ironically, the FCC's default rates have been set on the basis of cost studies that utilize an approach to cost estimation (*viz.*, the bottom-up approach) that is not especially well-suited to the difficulties of gauging indirect cost effects associated with incremental changes. The FCC justifiably wishes to minimize problems of arbitrary cost allocation. These problems necessarily arise given the uneconomic (perceived) statutory requirement to abjure from utilizing economically relevant demand-side information in setting rates.⁷

To minimize the markups needed to recover overhead burdens, the Commission seeks inclusive incremental cost measures that embody indirect cost effects and thereby limit the common costs to be allocated via arbitrary accounting convention. At the same time, it has relied upon cost estimation techniques that are comparatively ill-adapted to the problem of gauging indirect cost

⁶ In particular, rates for services with inelastic demands (*e.g.*, those lacking competitive alternatives) should be expected to rise.

⁷ The Commission claims that its approach will produce economically efficient rates. In reality, a (solely) cost-based approach is theoretically incapable of producing efficient rates (*See* W. J. Baumol and J. G. Sidak, *Toward Competition in Local Telephony*, 1994) and there are also compelling reasons to believe that a cost-based approach will suffer grave disabilities in practice. Indeed, the latter are precisely the reasons the Commission abandoned cost-based rate setting in favor of price caps.

effects. In our view, the combination of an inclusive conception of incremental cost (*i.e.*, one leaving little overhead to be allocated) with a miserly approach to the actual measurement of costs (*i.e.*, one not well-suited to pick up indirect cost effects) is a likely recipe for unrealistically low interconnection prices.

II. Strengths and Weaknesses of Alternative Estimation Procedures

As noted, there are two basic approaches to the empirical estimation of forward-looking incremental costs — bottom-up modeling and top-down modeling. Each approach has its strengths and weaknesses and each can provide a cross check on the other. To the extent the approaches produce differing estimates, differences can be traced back to inconsistencies in underlying assumptions and disparate treatment of key issues as well as the characteristic properties of the different approaches.

The bottom-up approach typically involves the construction of an economic-engineering model that identifies the technology components required to build and operate a particular incremental supply capability. One advantage of this approach is that it can, in principle, embody information about the costs of deploying state-of-the-art technology when and where appropriate to do so.

In the real world, output is supplied using a mix of current technology and older technology. Newer technology is phased in over time, as older technology is retired. This process can, however, take many years, because telecommunications plant is frequently long-lived. In addition, new technology can sometimes, but not always, be used efficiently to accommodate growth. For example, if growth is accommodated by deploying a new switch, the new capacity will presumably

embody latest technology. If growth is accommodated by expanding a current switch, the new capacity may embody an older technology.

To be most useful, a bottom-up cost model should reflect this mix of new and old technology. By doing so, it can estimate the actual costs that are likely to be incurred in handling various levels of output. Cost differences between alternative scenarios are critical for evaluating alternative regulatory policies.

Unfortunately, some analysts, most notably Hatfield Associates, Inc. (HAI),⁸ have not faced up to this difficult problem of specifying the mix of old and new technology. Instead, they have assumed that all output is accommodated using latest technology; *i.e.*, the green-field assumption. While this heroic assumption facilitates the analysis, the results are, as a consequence, far less useful. They do not provide even a reasonable approximation of the costs that will actually be incurred by an *efficient* incumbent as a result of alternative regulatory policies. Whatever economic efficiency may be associated with cost-based pricing cannot be achieved in practice if the cost estimates that are exploited misrepresent the costs that are likely to be incurred in the real world.⁹

A realistic bottom-up model requires a great deal of information. In addition to substantial data, many assumptions are needed regarding cost relationships. Such assumptions are inevitably

⁸ HAI. *The Cost of Universal Service*, 1994, and *The Cost of Basic Network Elements: Theory, Modeling and Policy Implications*, 1996.

⁹ At the FCC's *Economics of Interconnection Panel Discussion Forum*, Robert Crandall criticized the green-field approach from another perspective. He noted that the bottom-up approaches the Commission is relying upon differ significantly from the TSLRIC estimates that have been produced in the past for regulatory purposes and embody a high degree of intellectual arrogance:

[O]ne has to suspend belief when people who would like to enter suggest that they could improve upon the performance of the existing network. For them to suggest that ought to lead to a response from regulators to invite them to do it, and in fact to insist that they do it as a demonstration project.

subject to debate and criticism.¹⁰ There is always a danger that such intricate models will run amok and yield cost estimates that diverge substantially from reality.

Prudent application of top-down models is a good antidote for this potential problem. If bottom-up and top-down estimates differ substantially, regulators know that there is a substantial problem with one procedure or the other (or perhaps both). Reconciling such differences can avoid the use of cost models that have run amok. This is the approach regulators in the United Kingdom have successfully undertaken.

Oftel has undertaken a careful and thorough analysis of different costing methodologies in an effort to produce accurate and analytically meaningful cost estimates. Oftel has expended substantial efforts to understand the reasons why cost estimates differ and to reconcile conflicting estimates. This process has resulted in sound cost estimates in which both the regulator and the industry have confidence. It has increased the (already high) credibility of the government's policy. It has also had the highly beneficial effect of rendering Oftel's policymaking process highly transparent and lending its decisions a high degree of clarity. Interested parties have all been permitted and encouraged to participate in the process of reconciliation. Not only have the sources of differences been revealed, but significant efforts have also been made to reconcile differences. Where differences remain, it is clear why they remain and what specific tradeoffs the regulator is making. This, in turn, supplies a basis for inferring the regulator's revealed preferences and for comparing revealed preferences with stated policy objectives. Thus, there is policy transparency and the ability to readily assess the regulator's performance.

¹⁰ For example, the current debate on interconnection costs has included discussion of the reasonability of, *inter alia*, assumed input prices, appropriate engineering of the network, plant utilization rates, density zones, customer distributions within density zones, costs of capital and so on.

The bottom-up approach is most suitable where the hypothetical incremental changes being considered are relatively small and involve comparatively clearly delineated alterations to the *existing network*.¹¹ The approach becomes more questionable as the scope of contemplated incremental changes expands and becomes more radical (and less "incremental" in the common-usage meaning of the term).

The kinds of incremental changes the FCC contemplates, while still *conceptually* incremental, nonetheless involve quite large *elemental* changes: What would the network cost but for key elements of operations (*viz.*, switching, loops, *etc.*)?¹² For changes of this scope and magnitude, indirect cost effects are substantial. It is one thing to assume no change in, say, personnel department costs when ten employees are added; quite another to assume no change when one thousand employees are added. With the bottom-up approach, starting from first principles, it is not easy to fathom and get an empirical handle on the magnitude of such effects.¹³

The top-down approach draws forward-looking inferences on the basis of experience in building and operating the networks that actually exist in the real world. It does not simply embody conjectures about what might constitute an efficient set-up in an abstract Never-Neverland. The *econometric* top-down model we describe and estimate reflects operating experience in a diversity of operating environments and optimization decisions taken by real decisionmakers spending real

¹¹ Telephone companies have for many years undertaken bottom-up cost studies of this type.

¹² Clearly these conceptions strain definitional limits: It barely makes sense to conceive of networks without key, almost *sine qua non*, components and functionalities.

¹³ A shoddy bottom-up approach may simply overlook such effects. A more conscientious effort may make a conjecture about such costs, but such conjectures are likely to be just as contested as those involving direct-cost relationships.

money in a real-world business setting (notably, one in which private owners generally possess competing alternative outlets for their investments).

Utilization of pooled time-series cross-section data enables analysis of time trends and, thus, inferences about forward-looking values. This overcomes one seeming disability of an approach which exploits apparently inapposite historical data to make estimates of theoretically relevant forward-looking incremental costs. Furthermore, top-down estimates can (and should be) be based on economic valuation of capital. They are therefore *not* tied to embedded costs. In general, economic costs — not embedded costs — should be used to support inferences about forward-looking costs. A top-down model can provide estimates of economic costs based on real-world experience.

One potential downside of the top-down approach is its limitation in terms of estimating costs of new services (for which no directly relevant data may exist) or costs at fine levels of operational detail (for which available data may be too aggregated). As it happens, neither of these shortcomings precludes the use of a top-down approach for effective analysis of important interconnection inputs.

One final preliminary note is worth making. In the telecommunications industry, with its historical development and long-standing status as a regulated industry, incremental costs can, at best, supply only a *starting point* for pricing decisions. Where there are economies of scale and scope, or genuine overheads and common costs, or where some services are priced below incremental costs, or where past regulatory depreciation has been uneconomic and inadequate, pricing merely to recover incremental costs will not suffice to sustain the regulated firm's regulated activities. Nevertheless, it is important to get the starting point right. Misleading measures of incremental costs will only exacerbate the difficulties involved in establishing economically efficient prices.

III. Description of the Model

This section describes our top-down model. It is an econometric model estimated on pooled time-series cross-section data of telephone company costs and outputs. In an econometric model, incremental costs are quantified on the basis of the observed relationship between costs and outputs.

A. Density and Scale Economies

In our model, all cost and output variables are divided by square miles of serving area. Variables should therefore be interpreted as densities rather than absolute values. We additionally include square miles of serving area as an explanatory variable. That approach allows for the possibility that cost relationships vary with density.

We use a log-linear cost model. In such a model, the degree of scale economies is constant. It equals unity minus the output coefficient. Suppose, for example, that the output coefficient in a log-linear model is 0.9. Then, for each 1.0 percent increase in output, costs increase by only 0.9 percent. Such a model generates 10-percent scale economies ; *i.e.*, unity minus 0.9.

Since we divide variables by square miles of serving area, the estimated scale economies apply to geographic density — not absolute size. That is, they apply to expansion of output within a fixed geographic area. Contrary to many previous econometric cost studies, we find substantial scale economies in many equations. The reason is likely that scale economies with respect to density are more pronounced than those with respect to absolute size.

B. Time Trends

We tested time trends in each of our econometric equations to see how incremental costs vary over time. The estimated trends ranged between -3 percent per year and +3 percent per year for various components of costs. Most estimated trends were statistically insignificant. We therefore

do not include time trends in our estimated equations. In our sensitivity analysis, however, we use the estimated trends to forecast incremental costs for 1997, 1998 and 1999.

Our model is estimated using nominal data, unadjusted for inflation. Our finding of no significant time trend implies that incremental costs, *expressed in nominal terms*, do not change significantly from year to year. This corresponds to a decline in *real* incremental costs of approximately 3 percent per year.¹⁴

C. Model Specifications

Our econometric cost model consists of eight equations: one for each of the following categories of costs:

1. Loop investment;
2. Switching investment;
3. Support investment;
4. Cable and wire maintenance;
5. Circuit-equipment maintenance;
6. Switching maintenance;
7. General maintenance; and
8. Non-plant-related expense.

We exclude investment and maintenance associated with interoffice facilities and operator systems. Those costs are thus over and above the costs included in this study.

¹⁴ The decline in real incremental costs is related to productivity growth. The latter, however, reflects declines in *all* real costs — not just incremental costs.

1. Loop Investment

Loop investment consists of both cable/wire and circuit equipment. Both types of plant are also used for interoffice transmission.

The key explanatory variable in this equation is, of course, loops. That is, the dollar value of loop investment depends on the number of loops.

We also include a control variable to reflect possible cost differences between switched loops and unswitched loops. The variable is the sum of interstate special-access revenues and interstate switched-access revenues divided by interstate switched-access revenues. This variable equals unity if the company has no interstate special access. It significantly exceeds unity if special-access revenues are significant.

Unfortunately, data on intrastate unswitched loops (*i.e.*, special-access and intraLATA private lines) are lacking. We therefore (implicitly) use the interstate special-access variable as a proxy for those intrastate services as well. This treatment is not unreasonable. The large business customers that use interstate special access are primarily the same as those that use intrastate special-access and intraLATA private lines.

2. Switching Investment

Switching investment depends on both loops and dial equipment minutes (DEMs).¹⁵ Unfortunately, we cannot estimate their effects separately, because the two variables are highly correlated (multicollinear). Our approach is to develop three sets of estimates based on a broad range of alternative assumptions:

¹⁵ A DEM is one minute of use of one switch. A call that goes through two (or more) switches has two (or more) DEMs per minute of use.

- **Scenario (a):** The elasticity of switching investment with respect to loops is three times that with respect to DEMs;¹⁶
- **Scenario (b):** The elasticity of switching investment with respect to loops equals that with respect to DEMs; and
- **Scenario (c):** The elasticity of switching investment with respect to loops is one-third that with respect to DEMs.

In Scenario (a), switching investment is driven primarily by loops. In Scenario (c), switching investment is driven primarily by DEMs. Scenario (b) is an intermediate case.

Changing the assumption obviously affects the estimated incremental costs of loops and DEMs (in opposite directions). However, as shown below, the total revenue that would be yielded from pricing switching elements (loops and DEMs) at our estimated incremental costs is virtually identical in all three scenarios.

3. Support Investment

The key explanatory variable in this equation is direct investment; *i.e.*, investment other than support investment.¹⁷ That is, we posit that support investment is related to the amount of investment that it is intended to support.

4. Cable and Wire Maintenance

The key explanatory variable in this equation is cable and wire investment. The special-access control variable is also included in the equation. Maintenance costs include the costs of

¹⁶ Elasticity is defined in the usual way. In this case, it is the proportional change in switching investment divided by the proportional change in output.

¹⁷ Direct investment includes, *inter alia*, investment in interoffice facilities and operator systems. Even though such investment is excluded from our study, it may nevertheless require support investment.

handling rearrangements. Those costs, in particular, may differ between switched loops and dedicated loops.

5. Circuit-Equipment Maintenance

The key explanatory variable is circuit-equipment investment. The special-access control variable is also included in the equation. The cost of reconfiguring circuits (included as part of maintenance costs) may vary between dedicated circuits and switched-network circuits.

6. Switching Maintenance

The key explanatory variable is switching investment.

7. General Maintenance

The key explanatory variable is total investment.

8. Non-plant-related Expense

Non-plant-related expenses include primarily indirect costs; *e.g.*, the cost of headquarters operations. These expenses relate to the overall size of the company. We use total investment as an indicator of the size of the company. In the sensitivity analysis, we explore an alternative formulation in which non-plant-related expenses depend on total plant-specific expenses.

D. Different Types of Companies

Cost relationships may differ for different types of telephone companies. To allow for such differences, we estimated separate coefficients for Bell and non-Bell companies in each of the eight econometric equations. In some, but not all, equations, the differences between Bell and non-Bell companies are statistically significant.

In the sensitivity analysis, we additionally explored other ways to model differences among companies. We estimated a model in which incremental costs depend on size of holding company. We also estimated a model in which incremental costs depend on whether the company's serving

area includes major urban areas within the state. In this formulation, Southern New England Telephone, Lincoln Telephone, Centel in Nevada, and GTE in Florida, California, and Hawaii are combined with the Bell companies.¹⁸

IV. Data

The data used in the study are publicly-available data provided to NECA by local exchange carriers (LECs). The data relate primarily to expenses and investment. We also use data on loops, DEMs, square miles of serving area, and interstate access revenues. In the sensitivity analysis we additionally use USTA data on access lines of holding companies.¹⁹

The sample period for the study is 1990 to 1994. We were unable to include 1995 because DEM data for 1995 were not available.

The unit of observation for the study is a single local exchange carrier in a single state. We restricted our analysis to non-rural LECs, as defined by the Communications Act of 1996: *i.e.*, LECs with more than 100,000 loops in a state.²⁰

We included in the sample only those companies for which data were available for all five years (1990-1994). We excluded Rochester Telephone/Frontier in New York state, because the restructuring of the company may have significantly affected cost relationships. Additionally, we excluded Puerto Rico telephone companies; Puerto Rico's combination of low penetration and rapid

¹⁸ Cincinnati Bell would also have qualified, but it is excluded from our study because we do not have data on square miles of serving area.

¹⁹ USTA. *Statistics of the Local Exchange Carriers, 1991-1995* (for the years 1990 through 1994).

²⁰ We included LECs in the sample if they had more than 100,000 access lines in any year during the period (1990-1994).

growth may cause its cost relationships to differ significantly from those in other jurisdictions. In addition, we excluded six companies because of data problems. These data problems were:

- Negative values for quantities that must be positive (in reality); and
- Large year-to-year changes in plant that cannot be explained by normal operations. These changes may represent reclassifications of plant, purchases or sales of exchanges, and/or data errors.

The remaining sample consists of 380 observations (76 for each year). Of these, 46 observations for each year represent Bell Operating Companies; the remaining 30 observations for each year represent independent LECs.

V. Derivation of Incremental-Cost Estimates

A. Economic Value of Capital

Economic cost analysis should be based on the value of capital in use; *i.e.*, the economic value of capital. Valuing capital on the basis of regulatory depreciation is problematic because regulatory depreciation policies differ arbitrarily across jurisdictions. Furthermore, past regulatory depreciation in telecommunications has consistently understated declines in economic value (economic depreciation). As a result, the regulatory rate base now substantially exceeds the economic value of capital. That is, the regulatory rate base substantially overstates the value of capital in use.²¹

²¹ See J. H. Rohlfs, C. L. Jackson and R. M. Richardson, "The Depreciation Shortfall," filed before the Federal Communications Commission, CC Docket No. 96-262, *USTA Comments*, January 29, 1997, Attachment 15.

Our top-down cost estimates are based on estimates of economic value of plant. The base-case estimates of economic value are based on estimates of "theoretical depreciation reserves." In our sensitivity analysis, we additionally derive top-down cost estimates based on the economic values implied by Hatfield's green-field model.

1. Economic-Value Estimates Based on Theoretical Reserves

The price-cap LECs that are fully-subject to depreciation regulation recently filed estimates of their "theoretical reserves." Theoretical reserves are an accounting concept, based on estimates of economic lives of plant. The theoretical reserve is what the depreciation reserve *would be* if depreciation had, from the start, been based on (the LECs') current estimates of economic lives. In the same filing, we explained why we believe that theoretical net plant (*i.e.*, gross plant less theoretical reserves) is a conservatively high estimate of economic value.²²

Table 1 shows theoretical reserves and regulatory book reserves for each of several categories of plant. The table shows substantial disparities between theoretical reserves and regulatory book reserves for cable and wire (all accounts) and digital electronic switching.

²² *Ibid.*

Table 1 LEC Estimates of Depreciation Shortfall (Percent of Gross Plant)			
Reserve Percentage	Regulatory Depreciation Reserves (1)	Theoretical Reserves (2)	Shortfall (3)
			(2) - (1)
Overall	47.0%	54.0%	7.0%
Digital ESS	35.6	46.5	10.9
Digital Ckt.	51.3	53.8	2.5
Aerial Copper	57.8	69.6	11.8
Aerial Fiber	23.8	27.1	3.3
UG Copper	56.9	75.4	18.5
UG Fiber	27.4	33.0	5.6
Buried Copper	50.5	60.9	10.4
Buried Fiber	25.3	28.6	3.3
Aggregate Cable & Wire^a	52.1%	63.9%	11.8%
<p>• The values for aggregate cable and wire are estimated as follows: They reflect an estimate that 7 percent of cable and wire investment is fiber. That value is consistent with data on fiber investment of NYNEX, Pacific Telesis, SWB, and US West reported in J. M. Kraushaar, <i>Fiber Deployment Update End of Year 1995</i>, Industry Analysis Division, Common Carrier Bureau, FCC, July 1996, Table 9, together with data in the FCC's <i>Statistics of Communications Common Carriers, 1995-1996</i>. Since fiber investment is largely underground, we use the values of regulatory depreciation reserves and theoretical reserves corresponding to underground fiber. The remaining 93 percent of cable and wire investment is estimated to be copper cable. We weight the various categories of copper cable by aggregate LEC investment, as reported in <i>Statistics of Communications Common Carriers, 1995-1996</i>.</p>			
<p>Source: Data provided by LECs.</p>			

For our top-down model, we specially develop estimates of economic values for cable-and-wire plant and digital-switching plant. Those estimates differ substantially from regulatory book values. At the same time, we use regulatory book values as proxies for economic values of circuit

equipment and support plant. As Table 1 shows, the disparities between theoretical reserves and regulatory book reserves are not large for circuit equipment. We understand that they are also not large for the categories that comprise support plant.

As discussed in the previous section, each observation in our sample applies to a particular combination of company-state-year. For each such combination, we estimate an equation for loop plant (which consists largely of cable and wire, but includes some circuit equipment) and switching plant. We need to estimate economic value of cable and wire and switching equipment for each combination of company-state-year.

Our estimates are based on the aggregate ratios of theoretical reserves to regulatory book reserves in Table 1. In particular, for each company-state-year combination, we assume that:

$$EV_{C\&W} = GP_{C\&W} - 1.23 RDR_{C\&W} \quad (A)$$

$$EV_{Sw} = GP_{Sw} - 1.31 RDR_{Sw} \quad (B)$$

where,

EV = economic value;
 GP = gross plant;
 RDR = regulatory depreciation reserve;
 $C\&W$ = cable and wire;
 Sw = switching; and
the values 1.23 and 1.31 are the ratios of theoretical reserves to regulatory book reserves in Table 1 for aggregate cable & wire and digital ESS, respectively.

These estimates of economic value are substantially less than the regulatory book value of net plant.

The latter equals $GP - 1.00 RDR$.

For any age of plant, the regulatory reserve is proportional to the average regulatory depreciation rate that was in effect in the past. The theoretical reserve is proportional to the depreciation rate based on economic life. Eqs. (A) and (B) are therefore equivalent to the assumption that the aggregate ratio of economic depreciation to historical regulatory depreciation is the same for all company-state-year combinations (for each type of plant). That assumption obviously does not apply exactly in all cases. It is, however, a reasonable simplifying assumption for purposes of deriving aggregate estimates of costs.

These estimates of economic value should be used together with the implied estimates of economic depreciation expense. We use the following estimates of economic depreciation expense in our top-down analysis:

Cable and wire:	6.7 percent of gross plant (15 year economic life);
Switching:	10 percent of gross plant (10 year economic life);
Circuit:	12.5 percent of gross plant (8-year economic life); and
Support plant:	10 percent of gross plant (10 year economic life);

These depreciation rates are consistent with the companies' theoretical reserve calculations for cable and wire, switching and circuit.²³ We believe that the estimate of 10 percent for support plant is also reasonable.

²³ See Affidavit of L. Vanston, Technology Futures, Inc., *USTA Comments*, CC Docket No. 96-262, January 29, 1997.

2. Economic-Value Estimates Based on Hatfield's Green-field Model

In our recent filing on capital recovery, we observed that the Hatfield Model (HM) implies a theoretical reserve of 71 percent of gross plant.²⁴ The implied value of theoretical net plant (gross plant less theoretical reserves) is only 63 percent as great as the LECs' estimates of theoretical net plant.²⁵ Our estimates of economic values corresponding to the HM are simply 0.63 times those in Eqs. (A) and (B). That is:

$$EV_{C\&W} = 0.63 [GP_{C\&W} - 1.23 RDR_{C\&W}] \quad (C)$$

$$EV_{Sw} = 0.63 [GP_{Sw} - 1.31 RDR_{Sw}] \quad (D)$$

The estimate of economic depreciation corresponding to the Hatfield model is 1.31 times as great as that implied by the LECs' estimates of theoretical reserve. That is, 1.31 times as much depreciation expense is required (for any average age) of plant to generate reserves that are 71 percent instead of 54 percent. Thus, economic depreciation expense is as follows:

Cable and wire:	8.8 percent of gross plant (11.4 year economic life);
Switching:	13.1 percent of gross plant (7.6 year economic life);
Circuit:	16.4 percent of gross plant (6.1 year economic life); and
Support plant:	13.1 percent of gross plant (7.6 year economic life).

These estimates differ enormously from regulatory depreciation practice. They are also greater than the depreciation rates used by unregulated industries for similar types of plant.

²⁴ See Rohlfs, Jackson and Richardson, *op cit.*, p. 24

²⁵ This ratio is calculated as $(1 - 0.71)/(1 - 0.54)$.

We use the HM-based estimates of economic value and economic depreciation for sensitivity analysis. We do not defend the implied estimates of economic depreciation as being reasonable. We simply observe that economic depreciation must have been that rapid in order for the economic value of embedded plant to fall to the level estimated in the HM. Indeed, the possible unreasonableness of the implied estimates of economic depreciation may indicate problems with the HM.

B. Annualizing Factor

An annualizing factor must be developed in order to convert investment to annual costs. In our analysis, the annualizing factor has three components:

- Return to capital;
- Economic depreciation; and
- Taxes.

We use the FCC's allowed rate of return of 11.25 percent per year for our base-case cost estimates. We use estimates of economic depreciation, as discussed in the previous section. We use actual taxes accrued. These three amounts are expressed as percentages of the economic value of capital. The sum of these three components is then multiplied by the economic value of capital.

Some other cost models (*e.g.*, the HM) have been estimated assuming a return to capital of 10 percent. To derive comparable results, we performed a sensitivity run using that return to capital. Nevertheless, we believe that in reality the cost of capital may actually be higher than 11.25 percent per year, on a forward-looking basis. The LECs face competitive risk and considerable uncertainty regarding regulatory policies. For that reason, actual forward-looking incremental costs may exceed our estimates — especially those in the sensitivity run.

C. Calculation of Element Long-Run Incremental Costs

Investment involves direct capital costs. They are calculated by multiplying the amount of investment by the annualizing factor. Loops and DEMs have direct incremental costs to the extent that they cause investment.²⁶

Support investment is an indirect consequence of direct investment. Loops and DEMs cause investment in loops, interoffice facilities, and switching. These, in turn, generate the need for support investment. In our calculation of element long-run incremental costs (ELRIC), we take account of these indirectly caused costs, as well as direct costs.

Maintenance expenses are also indirect costs of investment. That is, loops and DEMs cause investment, which requires maintenance. The effect is doubly-indirect for maintenance of support investment. That is, loops and DEMs directly cause investment in loops and switching. Direct investment generates the need for support investment, which must in turn be maintained. We take account of all these indirect costs, as well as direct costs, in our calculation of ELRIC.

Similarly, we take account of the indirect causation that generates non-plant-related expenses. In the model, these expenses depend on investment and are a further indirect cost of the outputs that cause investment.

D. Total Element Long-Run Incremental Cost

The model can also be used to generate estimates of total element long-run incremental costs (TELRIC). Contributions to TELRIC from various cost categories are calculated as follows:

- For cost categories with only a single output driver, the entire cost of the category is part of the TELRIC of the output.

²⁶ Mathematically, incremental cost is the derivative of cost with respect to output. In a log-linear model, incremental cost can be estimated as average cost times the estimated coefficient.

- For cost categories with multiple output drivers, the contribution to TELRIC is the cost savings that would result from reducing a particular output to zero. The proportional cost savings are less than the proportional decline in output if there are scale economies.

VI. Model Interpretation

A. Coverage

The econometric model uses state-specific cost data. Those data reflect the cost allocations generally used to determine jurisdictional revenue requirements.

In our analysis, we implicitly assume that costs are separable by state. We then use the above allocated costs as proxies for the relevant economic costs. This procedure is a reasonable way to generate state-specific cost estimates, as required for regulatory purposes.

Our data exclude the costs associated with unregulated and detariffed activities. That exclusion improves our analysis, because the costs of unregulated and detariffed activities are not driven primarily by the output variables in our model.

Our cost data are "unseparated." That is, they apply to the sum of intrastate and interstate costs. Thus, our estimates do not depend on the Division of Revenues procedures used to allocate costs between intrastate and interstate jurisdictions.

B. Long Run Versus Short Run

Most of the variation in our econometric model is cross-sectional. Consequently, most of the explanatory power of the model relates to why costs differ across companies. Observed costs reflect the efforts of companies, over many past years, to optimize their production. It follows that cross-sectional cost differences can reasonably be regarded as differences in long-run costs. The

econometric model explains how these long-run cost differences relate to differences in output. For this reason, we interpret our incremental-cost estimates as estimates of long-run incremental costs.

VII. Econometric Results

This section presents our econometric results. We use the variance components (random-effects) method to estimate the model. This technique is widely used for estimation on pooled time-series cross-section data. It is based on a more general model of the structure of statistical errors (than that which underlies ordinary least squares). Our estimates of incremental costs based on this method of estimation are slightly lower than those based on ordinary least squares.

The equations are all estimated precisely. The r^2 statistic is 0.99 in all equations. Such fits are extraordinarily good in data that are largely cross-sectional. The general output coefficients also have tight confidence intervals. In all of the equations, the t statistics for the general output variables (but not the incremental Bell effects) exceed 10 — far in excess of the minimally significant level of 2.

As previously discussed, the output coefficients in the equations can be interpreted as unity minus the scale economies associated with increasing density. The Bell coefficients reflect the incremental effect for Bell Operating Companies. Hence, the total effect for Bell companies is the sum of the general coefficient plus the Bell coefficient. The significance level of the Bell coefficient indicates whether the Bell effects differ significantly from the general effects.